

TITLE OF THE INVENTION:

METHOD FOR SIMULATING MOBILITY IN AN URBAN AREA

5

The present invention relates to method for simulating mobility in an urban area.

BACKGROUND OF THE INVENTION

10 As is known, the methods for simulating urban mobility are suited for supplying a forecast of the evolution in time of the movement of vehicles and individuals within a determined urban area.

15 The currently known methods for simulating urban mobility assign to each individual and/or vehicle a precise, unique and deterministic destination, that is they determine the movements of individuals and vehicles, using deterministic formula of the origin-destination
20 type.

In particular, in the above-mentioned methods for simulating urban mobility, a specific route and a determined speed of movement are assigned to each
25 individual and to each means of transport, that is the movement of the individual and of the means of transport in the urban area are established a priori.

The above-mentioned methods for simulating urban mobility
30 present the problem that they exclude any situation of an uncertain nature that originates as the individual moves in the urban area.

SUMMARY OF THE INVENTION

35 The aim of the present invention is therefore to provide a method for simulating mobility in an urban area without

the problems described above.

According to the present invention a method for
simulating mobility in an urban area is supplied as
5 described in claim 1.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described with
reference to the annexed drawings, which illustrate a non
10 limiting embodiment, in which:

figure 1 illustrates a block diagram relating to a method
for simulating mobility in an urban area operating
according to the dictates of the present invention;

figure 2 illustrates a block diagram relating to some
15 operations carried out in the method for simulating
mobility in an urban area operating according to the
dictates of the present invention;

figure 3 illustrates a block diagram relating to some
operations carried out in the method for simulating
20 mobility in an urban area operating according to the
dictates of the present invention;

figure 4 illustrates a block diagram relating to some
operations carried out in the method for simulating
mobility in an urban area operating according to the
25 dictates of the present invention; and

figure 5 illustrates a block diagram relating to some
operations carried out in the method for simulating
mobility in an urban area operating according to the
dictates of the present invention.

30

DETAILED DESCRIPTION OF THE INVENTION

With reference to figure 1, a flow diagram is shown
relating to a method for simulating mobility in an urban
area suited for making a forecast of the mobility of
35 several individuals within a determined urban area.

In particular, the simulation method is suited for forecasting the evolution of a "system" comprising a plurality of "objects" which interact with each other according to a discrete stochastic formula, which
5 considers the mobility of each individual object, the variations of movement (flow variations) of a plurality of individual objects within the determined urban area, the restraints imposed by the bio-rhythms of the individual objects and by the chronotopical and
10 morphological structure of the urban area.

More particularly, in the simulation model one or more destination areas present within the urban area are assigned to a predetermined number of individual objects.
15

In other words, some individuals are assigned "tendencies" of movement towards one or more destination areas indicated below with the term "chronotopes", that is towards a plurality of geographically limited areas,
20 each one of which is within the urban area and is characterised by its own specific temporal dynamic.

In the method for simulating urban mobility, the "objects" included in the "system" are suited for defining
25 the individuals, the chronotopes, the nodes, the paths and the means of transport present within the urban area.

The chronotope objects in turn comprise place objects, while the node objects comprise the stop objects.
30 Each individual object is defined by the following parameters.

An individual code suited for unmistakably indicating each individual object, thus distinguishing it from the
35 other individual objects, and comprising information such as, for example, sex, age, social condition, etc.

A finite number of "charge" parameters each indicating the tendency of the individual object to move towards one or more chronotope objects. For example, a student type
5 individual object could include a "charge" indicating the student's tendency to move or not to move towards a university type chronotope object.

In particular, each of the "charge" parameters contains
10 an indication of the presence or absence of the tendency (of the on/off type, equivalent to present/absent) of an individual object to move towards a determined chronotope object.

15 Each individual object also comprises a vector suited to memorise a predetermined number NUM of movements performed by the individual object, and a status indicator suited for containing three statuses, each of which indicates a specific condition of mobility of the
20 individual object.

In particular, the individual object may present a first status indicating a condition of mobility in which he moves as a pedestrian, a second status indicating a
25 condition of mobility in which the individual object moves as a user, that is when he is moving on a means of transport object, and a third status indicating a condition of mobility in which the individual object is in a status of waiting, that is he is at a stop object,
30 waiting for a means of transport object.

Each individual object also comprises a parameter containing a value indicating the probability of movement of the same individual object towards a determined
35 direction.

Each individual object also comprises a "slowness" parameter indicating the slowing down of the individual object when moving on foot (pedestrian status) through a plurality of individual objects, and a minimum distance and threshold D_{MIN} , F_{MIN} indicating together a reference value suited to allow one to decide whether the individual object must move within the area in a random or non random manner.

10 The chronotope objects are defined by a limited area (present in the urban area) which is distinguished from the rest of the same urban area by means of its spatial character and its temporal rhythms of activity.

15 Each chronotope object is defined by the following parameters.

A name suited for identifying each chronotope object in the urban area; for example a hospital, a university, a cinema, a theatre, a sports centre, etc.

20 A geometric centre, a diameter, a number indicating the ends, a parameter indicating the number of node objects contained in the chronotope object, a parameter indicating which and how many place objects are contained
25 in the chronotope object, a parameter indicating the number of individual objects tending to the chronotope object.

The chronotope object is further defined by the following
30 parameters.

A parameter indicating the number I of individual objects present within the chronotope object in each instant of time, a parameter indicating a "field of attraction" that
35 is an attraction force F_{ATT} defined by a quantized elastic force which is cancelled within the chronotope

object in such a way that each individual object, which arrives at the chronotope object, begins a random movement.

- 5 In particular the attraction force F_{ATT} may be defined by the equation $F_{ATT} = -KX$ where K is a constant and X is the distance of the individual object measured with respect to the geometric centre of the chronotope object.
- 10 The chronotope object also comprises a number of steps of quantization of the "field of attraction" and a number of temporal steps which indicate the temporal dynamic of the chronotope, that is they define when the chronotope is "active" or "inactive".
- 15 Each chronotope object is in fact characterised by precise temporal rhythms during which the chronotope object itself is "active" and therefore "attracts" the individual objects which tend towards it, or "inactive" and therefore "does not attract" any individual object, irrespective of the tendency of the later. These temporal rhythms will be indicated below with the term "calendarisation".
- 20
- 25 For example, a university chronotope object may be "active" (accessible to individual objects) in a determined daily time interval (from 7.00 to 20.00), while a theatre chronotope object may be "active" (accessible to individual objects) in an evening time interval (from 21.00 to 24.00) and "inactive" the rest of the time.
- 30

In this case, the theatre chronotope object presents a different "calendarisation" from the university chronotope object, that is a different temporal dynamic.

35 Each node object presents at least one direction of

elementary movement towards at least one adjacent node and is defined by the following parameters.

A parameter indicating the adjacent node objects, a
5 parameter indicating the path objects that lead to the
node object or, parameter indicating the exits which lead
from the node object to the outside of the urban area
concerned, a parameter indicating the chronotope object
belonging to the node object, a parameter indicating the
10 number I of individual objects present in the node
object, a parameter indicating the friction $A(I)$ of the
node object and a parameter indicating a maximum friction
 A_M .

15 In particular, the friction $A(I)$ of the node object is
determined according to the number I of individual
objects present in the node object itself.

Each node object further comprises the following
20 parameters.

A finite number of local intensity values I_L indicating
the attraction force F_{ATT} exerted by each chronotope
object on the node object, a finite number of values
25 indicating the distances X_I from each chronotope object
present in the urban area considered and a vector which
identifies the geometric position of the node object in
the urban area.

30 Each node object finally comprises a parameter indicating
whether the same node object presents the stop function,
that is if it coincides with the stop object.

Each path object is suited for connecting each node to a
35 respective adjacent node and is defined by the following
parameters.

A parameter indicating the coordinates which define the initial and final point of the path object, a parameter indicating the number of exits of the path object from the urban area concerned, a path indicting how many and
5 which node objects are present in the path object, a parameter indicating (by means of a Boolean variable) whether the path object is or is not followed by a means of transport object.

10 Each means of transport object is defined by the following parameters.

A parameter indicating the position of the means of transport object, a parameter indicting the transport
15 line to which the means of transport object belongs, a parameter indicating the number UI and the codes of the individual objects that occupy the means of transport object, a parameter indicating the maximum capacity T_{MAX} of the means of transport object, a parameter indicating
20 the route of the means of transport object, or the coordinates of the stop objects that may be reached in sequence by the means of transport object and a vector indicating the stop objects.

25 In particular, the parameter indicating the stop objects comprises a plurality of values, each indicating a whole index which unmistakably identifies the stop object.

Each means of transport object further comprises a number
30 indicating how many stop objects the means of transport object encounters, a parameter indicating if the route is closes, that is if it is circular, or if it goes and comes back, a parameter indicating the speed of the means of transport object, a parameter indicating the
35 "slowness", that is, similar to the individual object, the slowing down of the means of transport object.

Each place object is defined by a determined circumscribed area comprised within a chronotope object.

- 5 For example the university chronotope object comprises a plurality of place objects, or departments (faculty of engineering, faculty of chemistry) presenting a temporal dynamic regulated by the chronotope object to which they belong.

10

The place object is defined by the following parameters.

- 15 A parameter indicating the chronotope object to which it belongs, a parameter indicating the maximum capacity I_{MAX} of the place object, the accessibility of the place object (a Boolean variable), a field which assumes a value zero outside the chronotope object with which the place object is associated, and a constant value within the chronotope object.

- 20 The place object is further defined by all the parameters that define the chronotope object.

The stop objects are defined by the following parameters.

- 25 A code unmistakably indicating the stop object, a parameter indicating the node object in which the stop object is situated, a parameter indicating the number and the codes identifying the means of transport objects present in a determined moment of time t at the stop object, a parameter indicating the maximum number of means of transport that may be contained by the stop object, a parameter indicating the number and the codes identifying the means of transport objects expected.

- 35 The stop object is further defined by all the parameters that define the node object.

With reference to figure 1, the method for simulating urban mobility arrives initially at block 100, in which the parameters of the objects described above are initialised.

In detail, the urban area "system" is defined in block 100, that is the urban area itself is "modelled" by means of a plurality of the objects described above.

10

In greater detail, in block 100 are initialised both the objects (path, chronotope, node, means of transport, stop) which form the structure of the urban area, and the individual objects involved in said urban area with their movements.

15

In particular, a correspondence (1-1) with the urban roads present in the area is associated with the path objects so as to provide a static spatial representation of the urban area itself.

20

Vice-versa, the node, chronotope and means of transport objects provide a temporal and dynamic representation of the urban area.

25

In detail, to each path object are assigned a predetermined number of node objects, the distance of which (one from the other) is defined by a number N_p of temporal steps taken by an individual object or by a means of transport object to reach a determined node, starting from an adjacent node.

30

Each temporal step is defined by a predetermined temporal unit DT_1 ; for example, two adjacent node objects can present such a distance that they may be reached by an individual object in a number of temporal steps $N_p = 8$,

35

that is in a time interval of $T = N_p * DT_I = 8 * DT_I$, and by a means of transport object in a number of temporal steps $N_p = 4$, that is in a time interval of $T = 4 * DT_I$.

- 5 It is opportune to point out that the "slowness" parameter (present in both individual objects and in means of transport objects) provides a value indicating a number of steps N_p to be added in the presence of friction $A(I)$ to the normal number of steps necessary to
10 cover the distance between two nodes.

In other words, the "slowness" is a parameter which indicates the number of temporal steps N_p during which the individual or means of transport object remains
15 stopped waiting for the friction $A(I)$ to decrease.

The block 100 is followed by the block 110, in which the temporal unit DT_I is initialised. In this way, the distances between the node objects are defined in terms
20 of temporal steps N_p .

In block 110 are also initialised an initial time T_s and a final time T_E which define a temporal window ($T_E - T_s$) within which urban mobility is simulated.
25

In block 110 are initialised, moreover, the number of temporal steps $N_p = 0$, and an event time which initially assumes the value $T_R(N_p, DT_I) = T_s$.

30 The event time T_R is updated by the number of temporal steps N_p according to the equation $T_R = (N_p * DT_I) + T_s$ and is suited for indicating the instant in time T in which the simulation of mobility occurs.

35 The block 110 is followed by the block 120, in which the individual objects are distributed, by means of a known

statistical function, on the urban area, that is on the node objects, on the chronotope objects, on the place objects and on the means of transport objects.

5 In particular, in block 120 the individual objects are distributed in the objects described above, considering both the tendency of each individual object to move towards a chronotope object and the status of activity/inactivity of the latter in the instant in time
10 $T=T_S$.

In block 120, each individual is therefore assigned a position and a condition of mobility indicating the status of movement of the individual object.

15 In particular, the condition of mobility can indicate a pedestrian status, in which the individual object is in a condition of movement on foot, a user status in which the individual object is in a condition of movement with a means of transport object, and a status of waiting in
20 which the individual object is present at a stop object to wait for the arrival of a means of transport object.

The block 120 is followed by the block 130, in which the
25 number of temporal steps $N_P=N_P+1$ is increased, and therefore also the event time $T_R = T_S + (DT_I * N_P)$.

The block 130 is followed by the blocks 140, 150, 160
30 170, 180 (which will be described in detail below), in which the chronotope, individual, node, means of transport and stop objects are updated.

Each of the blocks 140, 150, 160 170, 180 is followed by the block 190, in which the relation $T_R < T_E$ is checked.

35 In the positive case, that is if $T_R < T_E$, the block 190 is

followed by the block 200, in which the number of temporal steps $N_P=N_P+1$ is increased, and therefore also the event time $T_R=(N_P * DT_I) + T_S$, while if $T_R=T_E$, the block 190 is followed by the block 210, in which the simulation method is ended.

The block 200 is followed by the blocks 140, 150, 160 170, 180 within which takes place a new updating cycle of the objects in the new instant in time $T=T_R$.

In detail, in block 140 each chronotope object present in the urban area is updated at each temporal step N_P (and therefore the instant in time $T=T_R$).

In greater detail, in block 140, in the instant in time $T=T_R$, the parameter containing the number I of individual objects present in the chronotope object is updated.

In block 140 are also updated the place objects that form a part of each chronotope object.

In detail, for each place object the parameter indicating the accessibility of the place object itself is updated. In particular, this accessibility is determined according to the maximum capacity I_{MAX} of the place object and to the number I of individual object present in the place object.

In greater detail, if $I < I_{MAX}$ the place object is accessible, otherwise it is inaccessible.

Finally, in block 140 the activity/inactivity status (calendarisation) of the chronotope object is updated according to the event time T_R , that is it is estimated whether the chronotope object is active or inactive at the instant in time $T=T_R$.

In block 160 each node object is updated at each temporal step N_p and therefore at each increase of the event time T_R .

5

In particular, in block 160 are updated both the parameter containing the number of individual objects I present in the node object at the instant in time $T=T_R$, and the parameter indicating the friction $A(I)$ present between the individual objects moving in the node object itself.

10

In detail, the updating of the friction $A(I)$ in the node object is carried out according to the following equation $A(I) = I/R$ of a known type, in which R is a predetermined known constant.

15

In greater detail, if the friction $A(I)$ present in the node object is lower than a predetermined friction threshold $ARIF$ ($A(I) < ARIF$), the node object is considered free from friction and so the movement of the individual object is not liable to slowing down.

20

In this case the distance between two adjacent node objects is covered by the individual object in the initially predetermined number of temporal steps N_p (block 100).

25

If the friction $A(I)$ present in the node object is higher than or equal to the friction threshold $ARIF$, the movement of the individual object present in the node object in a determined instant in time $T=T_R$ is delayed according to the "slowness" parameter which supplies an increase value to the number of steps N_p necessary to cover the distance between two nodes.

30

35

In block 170 all the means of transport objects are updated at each temporal step N_p and therefore at each increase of the event time T_R .

- 5 In particular, in block 170 are updated both the parameter containing the number of individual objects I present in the means of transport object at the instant in time $T=T_R$, and the parameter indicating the stop object or node in which the means of transport object is
10 present at the instant in time $T=T_R$.

In block 180 all the stop objects are updated at each temporal step N_p and therefore at each increase of the event time T_R .

- 15 In particular, in block 180 are updated both the parameter containing the number of individual objects I present in the stop transport object at the instant in time $T=T_R$, and the parameter indicating the number and
20 the codes that identify the means of transport arriving at the temporal step N_p+1 .

- With reference to figure 2, a flow diagram is illustrated with relation to the updating of the individual objects
25 (carried out in block 150 of figure 1).

In detail, the updating of the individual objects begins in block 300.

- 30 The block 300 is followed by the block 310, in which it is checked whether the individual object has destination areas, or whether or not it tends towards a chronotope object.
- 35 In greater detail, the parameter containing the "charge" is controlled, indicating the tendency or otherwise

(on/off) of the individual object to move towards a determined chronotope object.

If the individual object has no destination area and therefore has no tendency (off) towards any chronotope object, the block 310 is followed by the block 320, in which the individual object itself is assigned a probability of uniform movement in the N directions of elementary movement (towards N adjacent nodes), that is it is assigned in an equiprobable (random) manner one of the elementary directions of movement which connect the node object (in which the individual object is situated) with the adjacent node object.

Instead, if the individual object tends (on) towards one or more chronotope objects, and depending on their status of activity/inactivity (calendarisation) is tending to one of theses, the block 310 is followed by the block 330, in which a preferential probability for the directions that favour the approach of the individual object to the destination chronotope object is overlapped on the equiprobability of movement in the N directions.

In this way the equiprobability of movement in the N directions is influenced by the value of the attraction force $F_{ATT} = -KX$ of the chronotope object on the individual object present in the node object.

In other words, the probabilistic component related to the directions that favour the approach of the individual object to the chronotope object to which it tends is increased.

The new direction of movement of the individual object is determined according both to the distance of the position of the individual object with respect to the destination

chronotope object associated with it and to the equiprobability of movement in the N elementary directions.

- 5 In block 320 and 330 a probable movement is therefore established for the updating of the position of the individual object.

10 The blocks 320 and 330 are followed by the block 340 in which the condition of mobility, that is the status of the individual object, is checked.

15 The block 340 is followed by the blocks 350, 360, 370 in which the status of the individual object at the instant in time $T=T_R$ is updated.

In particular, when user status is ascertained, the block 340 is followed by the block 350 in which the user status is updated.

- 20 If pedestrian status is ascertained, the block 340 is followed by the block 360 in which the pedestrian status is updated.

25 Finally, if waiting status is ascertained in block 340, the block 340 is followed by the block 370 in which the waiting status is updated.

30 The blocks 350, 360, 370 are followed by the block 380, in which the updating of the individual object is ended.

With reference to figure 3, a flow diagram is illustrated with relation to the updating of the user status (represented in block 350 present in figure 2) of an individual object.

35

The updating of an individual object presenting user

status begins with the block 400, in which it is checked whether the means of transport object containing the individual object is present in a stop object.

- 5 In the positive case, that is in the case of presence of the means of transport object in a stop object, the block 400 is followed by the block 410, in which an assessment is made of the "tendency" of the individual object to move towards a chronotope object, while, in the negative
- 10 case, the block 400 is followed by the block 420, in which the individual object is maintained in user status.

- If the individual object has no tendency towards a chronotope object, the block 410 is followed by the block
- 15 440, in which a transition is made, in a random manner, that is in an equiprobable manner, from user status to one of the three statuses.

- If user status is assigned in the block 440, the block
- 20 440 is followed by the block 450, in which the direction of movement of the means of transport object is assigned to the individual object.

- If waiting status is assigned, the block 440 is followed
- 25 by the block 460 in which the individual object remains in the stop object waiting for the arrival of a means of transport object.

- If pedestrian status is assigned in the block 440, the
- 30 block 440 is followed by the block 470, in which the individual object is shifted according to the direction of elementary movement determined in a random manner in the block 310 illustrated in figure 2.

- 35 If the individual object has a tendency towards a chronotope object, the block 410 is followed by the block

480, in which the local intensity of the attraction force F_{ATT} of the chronotope object on the stop object is compared with the predetermined minimum threshold F_{MIN} .

5 From the above description it should be pointed out that the attraction force F_{ATT} is determined ($F_{ATT} = -K \cdot D1$) according to the distance $D1$ of the stop object from the destination chronotope object.

10 If the attraction force F_{ATT} is below the predetermined minimum threshold $F_{ATT} < F_{MIN}$, the block 480 is followed by the block 440, in which, as described above, the new status of the individual object is assigned in an equiprobable manner.

15 If the attraction force is higher than the predetermined minimum threshold $F_{ATT} > F_{MIN}$, the block 480 is followed by the block 490, in which is recorded, as well as the first distance $D1$ of the stop object (in which is situated the means of transport object) from the destination chronotope object, a second distance $D2$ between the
20 latter and the stop object (involved by the means of transport at the next instant in time).

25 In the block 490 the ratio between the first and the second distance $D1/D2$ is calculated.

If the result of this ratio is below a predetermined threshold $S2$ ($D1/D2 < S2$), the block 490 is followed by the
30 block 420, in which the individual object is again assigned user status.

If the result of this ratio is above the predetermined threshold $S2$ ($D1/D2 > S2$), the block 490 is followed by the
35 block 500, in which is calculated a first temporal interval $T1$, which is given by the product of the time

unit DT_1 and the number of temporal steps N_{p1} necessary to reach the chronotope object on foot, starting from the node object ($T_1 = DT_1 * N_{p1}$).

- 5 In other words, the first temporal interval T_1 is equal to the time necessary for the individual object to reach on foot the chronotope object to which it tends.

In the block 500 a second temporal interval T_2 is also
10 calculated, which is given by the product of the time unit DT_i and the number of temporal steps N_{p1} necessary for the means of transport (which is moving in the direction of the chronotope object to which the individual object tends) to reach the stop object ($T_2 =$
15 $DT_i * N_{p2}$).

In other words, the second temporal interval T_2 is equal to the time taken by the individual object to wait for the arrival at the stop object of a means of transport
20 object which is moving in direction of the chronotope object to which the same individual object tends).

From the above description it should be pointed out that the first and the second temporal interval T_1 , T_2 also
25 depend on the "slowness" parameter present both in the individual object (movement on foot) and in the means of transport object.

Finally, in block 500 the value of the ratio T_1/T_2
30 between the first and the second temporal interval T_1 , T_2 is compared with a predetermined threshold S_3 .

If this ratio is higher than the predetermined threshold ($T_1/T_2 > S_3$), the block 500 is followed by the block 510,
35 in which a transition is made from user status to waiting status, while in the opposite case the block 500 is

followed by the block 520, in which a transition is made from user status to pedestrian status and the direction of movement established in block 320 of figure 2 is assigned to the individual object.

5

From the above description it should be pointed out that in waiting status the individual object waits for a means of transport object presenting a direction of movement that does not necessarily correspond to the direction of the chronotope object of the tendency, but such as to reach a stop object resenting a distance D1 from the chronotope object that is shorter than the distance presented by any one of the stop objects included in the route followed by the means of transport object on which the individual object previously presented user status.

10

With reference to figure 4, a flow diagram is illustrated with relation to the updating of the waiting status (represented in block 370 present in figure 2) of an individual object.

15

In this updating the individual object is of course present in a stop object.

The updating of the waiting status of an individual object begins with the block 600, in which it is checked whether the individual object ends or does not tend towards a chronotope object.

20

In the negative case, that is if the individual object has no tendency towards a chronotope object, the block 600 is followed by the block 630.

25

In the positive case, that is if the individual object has a tendency towards a chronotope object, the block 600 is followed by the block 610, in which is calculated a

30

35

first temporal interval T_1 , which is given by the product of the time unit DT_I and the number of temporal steps N_{P1} necessary to reach the chronotope object on foot, starting from the node object ($T_1 = DT_I * N_{P1}$).

5

In other words, the first temporal interval T_1 is equal to the time necessary for the individual object to reach on foot the chronotope object, starting from the stop object.

10

In the block 610 a second temporal interval T_2 is also calculated, which is given by the product of the time unit DT_I and the number of temporal steps N_{P2} necessary for the means of transport (which is moving in the direction of the chronotope object to which the individual object tends) to reach the stop object ($T_2 = DT_I * N_{P2}$).

15

In other words, the second temporal interval T_2 is equal to the time taken by the individual object to wait for the arrival at the stop object of a means of transport object which is moving in direction of the chronotope object to which the same individual object tends).

20

Finally, in block 610 the value of the ratio T_1/T_2 between the first and the second temporal interval T_1 , T_2 is compared with a predetermined threshold S_3 .

25

If this ratio is lower than the predetermined threshold ($T_1/T_2 < S_3$), the block 610 is followed by the block 620, in which a transition of the individual object is made from waiting status to pedestrian status and the individual object is shifted according to the direction predetermined in block 320 (illustrated in figure 2), while in the opposite case, that is if the ratio is higher than the predetermined threshold ($T_1/T_2 > S_3$), the

30

35

block 610 is followed by the block 630.

In the block 630 it is checked whether the means of transport object is present in the stop object.

5

In the negative case, that is if the means of transport object has not arrived in the stop object, the block 630 is followed by the block 650, in which it is checked whether the individual object presents a tendency for a chronotope object.

10

If the individual object has a tendency for a chronotope object, the block 650 is followed by the block 660, in which the individual object maintains waiting status.

15

If the individual object does not present any tendency, the block 650 is followed by the block 670, in which it is checked whether the waiting time T_A which indicates the time that the individual object remains in the stop object exceeds a maximum tolerable time T_{TOL} .

20

If $T_A > T_{TOL}$ the block 670 is followed by the block 680, in which the transition is made from waiting status to pedestrian status, while if $T_A < T_{TOL}$ the block 670 is followed by the block 690, in which waiting status is maintained.

25

If the means of transport object is present in the stop object, the block 630 is followed by the block 640, in which it is checked whether the number I of individual objects present in the means of transport object is equal to the maximum capacity T_{MAX} of the means of transport object (checking capacity).

30

If $I = T_{MAX}$ the block 640 is followed by the block 650 described above, while if $I < T_{MAX}$, the block 640 is

35

followed by the block 700, in which the transition is made from waiting status to user status.

5 With reference to figure 5, a flow diagram is illustrated with relation to the updating of the pedestrian status (represented in block 360 illustrated in figure 2) of an individual object.

10 The updating of the pedestrian status of an individual object begins with the block 800, in which it is checked whether the pedestrian object is in a stop object.

15 In the negative case, that is if the pedestrian object is not present in a stop object (and is therefore present in a node object), the block 800 is followed by the block 810, in which the individual object maintains pedestrian status.

20 The block 810 is followed by the block 820, in which the tendency of the individual object is checked.

25 If the individual object has a tendency towards a chronotope object, the block 820 is followed by the block 830, in which the individual object is shifted according to the direction established in block 320 (illustrated in figure 2), while in the opposite case the block 820 is followed by the block 840, in which the individual object is shifted according to the causal direction established in block 310 (illustrated in figure 2).

30

If the pedestrian object is in a stop object, the block 800 is followed by the block 850, in which is calculated a first temporal interval T_1 , which is given by the product of the time unit DT_i and the number of temporal steps N_{p1} necessary to reach the chronotope object on foot, starting from the node object ($T_1 = DT_i * N_{p1}$).

35

In the block 850 a second temporal interval T_2 is also calculated, which is given by the product of the time unit DT_I and the number of temporal steps N_{P2} necessary for the means of transport (which is moving in the direction of the chronotope object to which the individual object tends) to reach the stop object ($T_2 = DT_I * N_{P2}$).

10 Finally, in block 850 the value of the ratio T_1/T_2 between the first and the second temporal interval T_1 , T_2 is compared with a predetermined threshold S_3 .

15 If this ratio is higher than the predetermined threshold $(T_1/T_2) > S_3$, the block 850 is followed by the block 860, in which it is checked whether the means of transport object is present in the stop object, while in the opposite case the block 850 is followed by the block 810 described above.

20 If the means of transport object has not arrived in the stop object, the block 860 is followed by the block 870, in which it is checked whether the individual object has a tendency for a chronotope object.

25 If the individual object has a tendency, the block 870 is followed by the block 880, in which the transition of the individual object is made from pedestrian status to waiting status.

30 If the individual object does not have any tendency, the block 870 is followed by the block 890, in which a transition is made, in an equiprobable manner, from pedestrian status to waiting or respectively pedestrian status.

35

If waiting status is assigned, the block 890 is followed by the block 900, in which the transition of the individual object is made from pedestrian status to waiting status.

5

If pedestrian status is assigned in block 890, the block 890 is followed by the block 910, in which the individual object is shifted according to the causal direction established in block 310 (illustrated in figure 2).

10

If the means of transport object is present in the stop object, the block 860 is followed by the block 920, in which it is checked whether the number I of individual objects present in the means of transport object is equal to the maximum capacity T_{MAX} of the means of transport object.

15

If $I = T_{MAX}$ (maximum capacity reached) the block 920 is followed by the block 870 described above, , while if $I < T_{MAX}$, the block 920 is followed by the block 930, in which the transition is made from pedestrian status to user status.

20

Preferably, but not necessarily, the method for simulating urban mobility carries out in block 310 (in which the movement of an individual object without tendency is established) the control of the last N node objects previously "visited" and memorised.

25

The method for simulating urban mobility determines the new movement in an equiprobable manner, considering that the last N node objects previously "visited" cannot be visited before N temporal steps N_p have elapsed.

30

From the above description it should be pointed out that, in the method for simulating urban mobility, if an

35

individual object presents a "slowness" (calculated according to the friction $A(I)$ present in the node object in which the individual object is situated) higher than a predetermined threshold, for example equal to one, the movement of the individual object is accomplished only after a number of temporal steps N_p equal to the "slowness" have elapsed, unless in the meantime the friction $A(I)$ present in the node object has fallen below the predetermined threshold (de-crowding of the node object).

Finally it should be pointed out that, if an individual object with a tendency arrives in a chronotope object of tendency, and this chronotope comprises one or more place objects, the short range field parameter of these latter means that an individual object remains still in the place object and therefore in the chronotope object for a period of time equal to the activity time of the chronotope object.

The method for simulating urban mobility presents the advantage of simulating the evolution of urban mobility more realistically than the methods currently known, as it considers both the intentions of the individuals to go towards determined places, and the uncertain nature of the movement made through the urban area by each individual.

The method for simulating urban mobility in fact allows the study of the critical nature of one or more control parameters, considering the urban area as a complex "system" which organises itself and is able to manage the "tendencies" and the individual requests of mobility.

The method for simulating urban mobility may also be implemented to advantage by means of an electronic

calculator, which allows the graphic display of the objects described above and their temporal evolution, thus allowing a direct control of the dynamic of the "system".

5

In particular, this implementation advantageously allows the consequences of a determined urban planning to be forecast, that is it allows the interactions between the objects included in the "system" to be checked and any parameter characterising the urban area itself to be altered beforehand so as to cancel or reduce any possible critical status of urban mobility.

10

11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2194
2195
2196
2197
2198
2199
2200
2201
2202
2203
2204
2205
220